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upon close inspection, I found to be a multitude of caterpillars, a half-inch in length and one-thirty-second part of an inch in diameter; head of a dull red or brownish color, bodies smooth and somewhat glistening.

"These worms moved upon one another, piled upon and irregularly interwoven among each other like a flattened rope. The head of the column was much broader than the rest, being two inches wide, from which dimension the column gradually tapered (to a point, I suppose, for I did not see the end of it). The length of the column was four feet to a fence, beyond which I did not examine it.

"A portion of the column lay in the grass, through which it moved without interruption, as if it had been a solid mass. The rate of motion was extremely slow, not exceeding one-eighth of an inch in a minute. The color of the mass was as much like a rope of tow which has been exposed to the weather as anything I can think of; it might be called a rusty gray. The column was not cylindrical,—that is, a cross section would be elliptical."

"The Springfield (Mass.) Republican of August, 1865, gives an account of a 'reptile' found at Lee. It was nearly four feet in length, about the size of a man's finger, and shaped like a whip-lash; and on close examination the whole body was found to be composed of small worms about half an inch in length, with large black heads, and semi-transparent body. On separating them into fragments, they would immediately re-form into a snake-shape, and crawl slowly off. One or two similar snakes have recently been seen in that vicinity.' This was copied into the Lancaster Evening Express of Saturday, Aug. 12, 1865."

The Mechanical Theory of SOLAR HEAT.

BY JACOB ENNIS.

During the last quarter of a century scientific men have endeavored by new methods to account for the heat of the sun, and they now generally believe, or incline to believe, in its mechanical origin. Some adopt the meteoric theory. They suppose that meteorites are falling with great velocity in the sun, and that these stones strike the enormous solar fire by their fall. Others adopt the nebular theory. They suppose that the sun and all his attending planets and satellites have condensed from a very rare nebulous condition, and that the mere condensation, or falling together of their materials by the force of gravity, has produced all the solar heat. Others again combine both these theories. They believe that originally the sun and the earth were heated to a fused condition by mere condensation, and that since then the meteorites have continued the heat of the sun. The only source of heat by all these theories is gravity, because gravity causes the fall of matter, whether in a nebulous or a meteoric condition, and this falling, this mechanical force, is converted into heat. My object in this paper is to show that none of these views can stand the test of numbers and of well established facts. The high place which the mechanical theory of solar heat now holds in the scientific world, is my apology for this appearance.

Some of the important statements of the highly distinguished gentlemen who have formed the mechanical theory are these:

I. Dr. Julius Robert Mayer, of Heilbronn, says that a mass of burning coal equal to that of the sun would supply his present emission of heat only 4600 years; and that a meteorite falling into the sun would supply at least 4600 times more heat than the same weight of burning coal. Hence a mass of meteorites equal to the sun would supply his heat $4600 \times 4600 = 21,160,000$ years. This would be the least amount of heat when, as is most natural, that mass of meteorites should approach the sun spirally. If they should fall in a direct line, as would be most unlikely, the heat would be double this amount. This greatest possible amount of heat, being out of probability, is

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not taken into the account. Let it be clearly understood that the above 21,160,000 years of heat are to be derived not from the materials of the sun falling together, but from a mass of meteorites equal to the sun falling into the sun; the gravity of the sun not being thereby increased. The substance of the meteorites are supposed, by Mayer's theory, to be radiated away into space just as fast as they fall. The two ideas are vastly different. But how long would be the duration of solar heat by the mere falling together of the solar mass from infinite space? We may compute an answer from other statements of these gentlemen, as follows:

II. Speaking of the enlargement of the sun by the continued fall of meteorites, Dr. Mayer says: "the increase of volume could scarcely be appreciated by man; for if the specific gravity of these cosmical masses be assumed to be the same as that of the sun, the enlargement of his apparent diameter to the extent of one second, the smallest appreciable magnitude, would require from 33,000 to 66,000 years." These two periods are derived, the one from the spiral and the other from the direct fall. We will take the most probable medium,—say 41,360 years. A second of measure at the distance of the sun is about 470 miles. These turned into feet would be $470 \times 5280 = 2,481,600$ feet. An increase in the sun's diameter this number of feet in 41,360 years would be 60 feet in one year. Prof. Wm. Thomson, of Edinburgh, says that the fall of meteorites necessary to keep alive the present supply of solar heat would amount to an increase in the sun's diameter of one mile in 88 years. This again would be 60 feet in one year. At this rate of increase we may learn in how long a time the sun would grow from a mere point to his present size; or, in other words, how long would be the duration of solar heat from the falling together of the present mass of the sun. Thus, when the sun had only one-half its present diameter, it had only one-eighth of its present volume and mass, and its force of gravity was only one-eighth of what it now is. Therefore eight times its present fall of materials would be necessary. Its surface was only one-fourth as large, and hence, on this latter account alone, the stratum of meteorites would be thickened four-fold. Hence, when the sun had one-half of his present diameter, the annual thickness of the stratum of meteorites would be $30 \times 8 \times 4 = 960$ feet. Here we have an arithmetical progression. For the first year or term the number is 30; for the last year or term the number is 960. The sum of all the terms is $220,500 \text{ miles} \times 5280 \text{ feet per mile} = 1,164,240,000 \text{ feet}$. Now what is the number of terms or years necessary for this number of feet, the sum of all the terms? Let y be the number of terms. Then

$$\begin{array}{r} 30 + 960 \\ \hline 2 \end{array} \times y = 1,164,240,000$$

$$y = 2,352,000 \text{ years.}$$

Hence, from this mode of calculating, the sun, from one-eighth of his present size, would grow to be what it now is in 2,352,000 years. This, however, is but an approximation. We have taken the force of gravity to be no stronger in proportion to its mass than on the present surface; whereas nearer its centre it would be stronger; and there would be 220,500 more miles to fall. But our approximation is near enough for our present purpose, and we come to the conclusion that the entire falling force of all the materials of the sun, when gravitating together, would supply the present rate of heat not more than 3,000,000 years.

III. In remarkable contrast to the last statement, we have the following from Prof. Herman L. F. Helmholtz, of Heidelberg: "Let us make this addition to our assumption: that, at the commencement, the density of the nebulous matter was a vanishing quantity, as compared with the present density of the sun and planets; we can then calculate how much work has been performed by the condensation; we can further calculate how much of this work still exists in the form of mechanical force, as attraction of the planets towards the sun, and as *vis viva* of their motion, and find by this how much of 1867.]

the force has been converted into heat. The result of this calculation is that only about the 454th part of the original mechanical force remains as such, and that the remainder, converted into heat, would be sufficient to raise a mass of water equal to the sun and planets taken together, not less than 28,000,000 degrees of the centigrade scale. If the mass of our entire system were pure coal, by the combustion of the whole of it only the 3500th part of the above quantity would be generated." There is much ambiguity here in the words "remains" and "remainder." Prof. John Tyndall, of the Royal Institution, London, in his excellent work on "Heat as a Mode of Motion," takes both words to refer to the same thing. But really "remains" refers to the force still in store, as the attraction of the planets to the sun, and the *vis viva* of their motion. The "remainder" refers to the force of gravity already converted into heat during all past time. This past time has been so long that the burning of the solar system as pure coal would have furnished the heat for only the 3500th part of the time. But Mayer says that the burning of so much coal would last only 4600 years. Therefore $3500 \times 4600 = 16,100,000$ years for all past time, since the sun has been giving light and heat as he now does. Thomson says that a mass of carbon entering the sun, and burning with oxygen, would give out heat only equal to the 3000th part of its heat produced by the fall. Mayer says a meteorite, by its fall into the sun, develops from 4600 to 9200 times as much heat as would be generated by the burning of an equal mass of coal. If we take Mayer's lowest number, the most probable, the period would be $4600 \times 4600 = 21,160,000$ years. Thomson has given tables to show that the store of heat in the solar system, as the attraction of the bodies and as the *vis viva* of their motions, would last 45,723 years. Helmholtz says this is only the 454th part of the original store. Hence $45,723 \times 454 = 20,758,242$ years; a result remarkably near the above 21,160,000, and very far from the 3,000,000 years which I have attained from the data of Mayer and Thomson. The question now occurs, by what process of calculation has Helmholtz made the original falling force 454 times greater than what still remains, and that it would supply our heat for 21,160,000 years, instead of the approximation of 3,000,000 by my process above? I suppose he has done so by calculating the heat derived from the falling of a mass equal to the sun into another mass of the same amount; the gravity of the sun being not thereby increased, according to Mayer's theory! Mathematics have never been my leading study, and I have not the time for calculating the amount of heat to be developed in years by the falling of the materials of the sun from infinite space down to as near the centre of gravity as we now behold them. It would be an addition to science were some professed mathematician to publish this result by a method different from the one above by which I obtained the 3,000,000 years.

IV. The following statement of Helmholtz has been often quoted, and is still going around: "With regard to the store of chemical force in the sun, we can form no conjecture, and the store of heat existing therein can only be determined by very uncertain estimations. If, however, we adopt the very probable view that the remarkably small density of so large a body is caused by its high temperature, and that its density may become greater in time, it may be calculated that, if the diameter of the sun were diminished only the ten-thousandth part of its present length, by this act a sufficient quantity of heat would be generated to cover the total emission of 2100 years." Another form of the same statement has since been made, as follows: "If the sun be still contracting, the falling force thus brought into action would be sufficient to supply all the energy expended by the sun's radiations, if the contraction of the sun's diameter should only amount to one part in twenty millions in a year." This latter statement is derived from Helmholtz in this way: According to him, the surface of the sun must fall in all around towards the centre 110 feet every year to produce our present annual supply of heat. But 110 feet is the 21,000,000th part of the sun's radius. The entire statement seems

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to me in very strange contrast with all the others we have just reviewed. It amounts to nearly this: If the sun should contract in volume from what it now is to half its present diameter, this falling of its surface less than a quarter of a million of miles would afford solar heat for ten millions of years. Whereas the falling of its surface, by contraction, through many thousand millions of miles, has produced heat enough for only double that period, according to Helmholtz, and for only 3,000,000 years, according to my calculation already made in this paper. To me this statement about a supply of heat for 10,000,000 years to come seems more erroneous by far than the one about heat for 20,000,000 years of the past by mere falling force. His processes for arriving at these conclusions are not given; until they are given, the mere assertions seem plainly contradicted by reliable data already reviewed.

After these statements of the mechanical theory of solar heat, we will now examine the objections to its various phases.

V. That phase of the mechanical theory which assumes that the heat of the sun proceeds from his own condensation by the force of gravity, is objectionable on account of the short supply of heat. It would be only twenty millions of years, according to the longest statement, which I think I have shown to be erroneous. That twenty millions of years are plainly due to the falling together of two masses, both equal to our sun. Three millions are nearer the truth, which is obtained by the rate of growth in the sun, according to the meteoric theory. But even twenty millions of years are nothing when compared with the vast lapse of time, or rather of eternity, that is past. The experiments of Bischof on basalt show that for our globe to cool down from 2000 degrees to 200 degrees centigrade, would require 350,000,000 years. This result has been quoted and approved extensively by the highest authorities, among others by Helmholtz, and by Tyndall in his work on heat. Undoubtedly our globe was heated to a point as high as 2000° C. In "The Origin of the Stars" I have shown that the simple chemical elements composing our globe were created separately and uncombined, that they could not have combined slowly, but that they must have combined freely and rapidly, and in so doing our globe must have been all aflame, like the sun. Then for our earth to cool from 300° C. down so far as to be habitable for plants and animals, would require one hundred or two hundred millions of years more. Then come the long periods for the deposition of the fossiliferous strata; and these, the longer they are studied, seem to require longer and longer periods of time. This is my experience, after studying them forty years. Darwin computes, from data which seem sound, that 300,000,000 years have elapsed since the period of the weald, the latter part of the secondary. This latter part of the secondary, along with the tertiary, forms but a very small part of the stratified rocks. But we have been speaking only of the solid and the fused conditions of our planet. My many years of study on the nebulous condition of the great globes of space, impress me with nebulous periods equally as long and as incomprehensible as the fused and the solidified periods. In this way, while studying the monuments of the past set up by the Creator of the Universe for our guidance, our reason carries us back not only hundreds of millions, but thousands of millions of years, and, in endeavoring to conceive of these long periods, the mind is just as completely overburdened and bewildered as when we try to conceive of the immensity of space revealed by astronomy. By the side of all this how insignificant appears the three millions of years taken by the sun to give out his light by the mere falling force of his own materials. Even the twenty millions of years advocated by some appears no better. Therefore this phase of the mechanical theory of solar heat is untenable. Neither can it account for the former igneous fluidity of our globe. During the slow nebulous condensation the heat from that source must have slowly radiated away, and we must look to the chemical combination of its elements for its former fused condition.

VI. Mayer, the first originator of the meteoric theory of solar heat, calculated 1867.]

lated that the yearly accumulation of meteoric matter on the sun would so greatly increase the centripetal force of the solar system as to shorten our years from $\frac{3}{4}$ to $\frac{2}{3}$ of a second. This shortening of our years does not agree with our present astronomical observations. Moreover Laplace proved, from the observations of Hipparchus, that during the last 20 centuries our days have not been shortened by the one-three-hundredth part of a second. To escape this difficulty Mayer proposed the extraordinary idea that, by the undulatory theory, as well as by the old corpuscular theory of Newton, "the sun, like the ocean, is all the while receiving and losing equal quantities of matter." All the matter of the meteorites must be repelled back into space just as fast as they fall. But this is in direct contradiction to the theory of the conservation of force. The force imparted to the sun by the fall of meteorites might indeed repel them all back again precisely where they came from, providing there existed a condition of perfect elasticity. But this elastic rebound would completely exhaust all the force received by the fall, and no force could be left to be converted into light and heat. To make the sun give out light and heat with a force equivalent to the fall, and also to send back the meteors with a force equivalent to the fall, would be making the sun perform exactly double duty. Still another objection arises, equally as strong: It would be like saying that when a body burns, the products of combustion are radiated away in the forms of light and heat. But experiments in abundance have proved that chemical combinations lose none of their materials by light and heat. It would be hard to find a more clear or a more acute mind than that of Mayer, and yet, to save his grand and magnificent meteoric theory, he was led, no doubt reluctantly, to this idea of immense quantities of matter radiated away by the undulatory theory. We may say immense quantities, because the radiation of the sun would amount to his entire mass in 3,000,000 years; and a mass equal to the great globe on which we dwell in the lifetime of an aged man.

VII. Professor Wm. Thomson, of Edinburgh, endeavored to save the meteoric theory by a very different method. He supposed that meteorites are revolving around the sun within the earth's orbit, and that they appear to our vision in the zodiacal light. Being resisted by the solar atmosphere, they fall in the sun, and being already within our orbit their fall does not shorten our year. There are two objections to this phase of the meteoric theory. The first is that it does not allow time enough for geological facts. For the stability of the solar system, the meteorites must revolve around the sun in the same direction as the planets. They must come down spirally and hasten the rotation of the sun. Assuming that before their fall the sun did not rotate on its axis, then, to keep up the present emission of heat, the meteorites, according to Thomson, would give the present velocity to the sun in 32,000 years. Therefore sunlight has existed only during the past 32,000 years. Therefore the fossil plants away down in the lowest strata of our earth lived and flourished and were nourished by the light of the sun only 32,000 years ago! Sir Charles Lyell, in his *Antiquity of Man*, calculated that the bones and implements of men, found in what may truly be called superficial strata, are at least 100,000 years old, and in this I believe he is now supported by the assent of all geologists.

The second objection to Prof. Thomson's phase of the meteoric theory, is that it opposes not only the geological, but also the nebular theory. The nebular theory must no longer be regarded as a vague hypothesis, but as a scientific verity. In *The Origin of the Stars*, and in a paper in this volume of these Proceedings, I have proved mathematically that the velocities of all the members of the solar system, more than a hundred in all, are just such as they must have by the force of gravity acting according to the nebular theory; and that not only their various velocities, but the directions of their complicated motions, and the positions of their orbits, are just what the force of gravity would necessarily produce. I have given evidences equally as

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strong that gravity imparted all their motions to all the stars in their orbits, as we have ever had that gravity now holds them in those very orbits. For these and many other reasons the nebular theory must be regarded as established. The supposition that the rotation of the sun has been caused by meteorites is directly opposed to the very foundation of the nebular theory, which teaches that the original rapid rotation of the sun by centrifugal force produced all the planets, planetoids, and also these very meteorites of the zodiacal light, if such there be. These meteorites must have had the same origin as the other members of the solar system, because they move in the same plane and in the same direction. Therefore these meteorites, if such there be, have derived their velocities from the sun, and not the sun from the meteorites. The wonder is, not that the sun now rotates so rapidly, but so slowly. When his surface extended to the orbit of Mercury his velocity of rotation was 110,000 miles per hour. Now it is only 4560 miles per hour. How has it been retarded? I have shown that in many, probably in most, cases the rotation of a nebula can be only on the surface, and that ultimately it must be retarded by friction on the unrotating interior. Between the orbit of Mercury and the present surface of the sun, the velocity of rotation must have been vastly increased in order to abandon any planetary or meteoric matter. But in reality the velocity was decreased, and therefore none could have been abandoned. Even before the abandonment of Mercury, there was a slackening of the rate of increase in solar rotation. It is on this account that the interplanetary space between Venus and Mercury is greater than that between the Earth and Venus, contrary to the law of all the other planets. For all the interplanetary spaces become less and less in approaching toward the sun, in consequence of the greater rate of nebular rotation. Therefore, in consequence of the slackened rate of rotation, we could look, according to the nebular theory, for no large mass of meteoric matter abandoned by the sun inside the orbit of the earth. But, for argument sake, let us suppose that a large amount of meteoric matter was thus abandoned, and let it be equal to the mass of Venus. This truly is a very liberal allowance. Then how long would its fall in the sun keep alive his present rate of heat? According to Thomson, the fall of Venus in the sun would prolong his heat just 83 years and 227 days. This is a wonderful contrast with the inconceivable millions of years demanded by the other facts of science.

Mayer's phase of the meteoric theory is also opposed to the nebular theory. I suppose he must have seen that the present interior heat of the earth and its former entire igneous fusion could not be accounted for by the fall of meteorites, because they must have ceased gradually, and we would now find a thick crust of meteoric matter on the surface of our planet. He therefore supposes that the heat was caused by a collision with another large body. This collision must have produced not only the heat but also the rotation of the earth. The same must have occurred with the moon, because the lunar mountains and volcanoes exhibit unmistakeable evidences of former fusion and interior heat. The same also must have happened to the other planets and satellites, for they all rotate. Therefore, according to this view, each of the planets and satellites must have found a fellow to strike them, most wonderful to tell, precisely in the same way, and impart to them all their rotations in the same direction! But the solar system is constructed on different principles. There can be no collision of large planetary bodies; much less a very peculiar system of collisions to make them all rotate and move in their orbits exactly in the same way!

Thus we see insurmountable objections against all the three phases of the mechanical theory of solar heat. The old theory of luminous, calorific, cloud-like envelopes floating in the atmosphere of the sun, is very generally given up; but even this does not attempt to point out the cause of the heat in the supposed envelopes. There remains only the chemical theory, which has but the one objection, that there is not a sufficient amount of fuel in the sun.

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This objection I have shown, in *The Origin of the Stars*, to be founded on at least three groundless assumptions; founded, in fact, on our ignorance. It pretends to say that the materials of the sun, pound for pound, can give out no more heat than the materials of the earth. It pretends to say that the physical forces, all alive in the sun, can produce no more heat in connection with chemical combination than in our laboratories. It pretends to say that in the condensation of the sun no new chemical elements can be produced to serve as new fuel. It pretends all this in profound ignorance of what it ought to know for such assertions. On the contrary, I have shown various probabilities that the vastly different materials of the sun give out unspeakably more heat. I have shown various probabilities that all the physical forces alive together in the sun can produce more heat in connection with chemical combination than in our little laboratories. I have shown, what seems to me conclusive proofs, that new chemical elements are now forming in the sun to serve as new fuel. These probabilities I do not call my demonstration. But beyond all this I have given, as my special demonstration, large numbers of facts and arguments, derived from the earth, the sun and the fixed stars, to prove that solar heat springs from chemical action. Until some one in the scientific world attempts to answer my facts and arguments, I need say nothing further.

There are many other objections to the mechanical theory, but I think quite enough have here been given to put the discussion at rest forever.

Descriptions of Five New Species of Central American BIRDS.

BY GEO. N. LAWRENCE.

1. *GLAUCIS AENEUS*.

Front and top of the head dull brown, upper plumage besides of a shining coppery bronze, the upper tail coverts are rather more bronzy, with dull grayish margins; the two central tail feathers are of a dull pale bronzy green, the other tail feathers are chestnut at base, with a broad subterminal band of black, all of them end in white; ear coverts black; a pale rufous stripe runs from the bill under the eye, and there is a postocular mark or streak of the same color; a dusky line extends from the under mandible down each side of the neck; the entire under plumage and under tail coverts are of a clear rufous; upper mandible black, the under is dull yellow for two-thirds its length, with the end black; feet pale yellow.

Length (skin) $4\frac{1}{2}$ in.; wing 2 1-16th; tail $1\frac{1}{4}$; bill $1\frac{1}{4}$.

Habitat.—Costa Rica. Collected by A. R. Endrés. Type in Museum of Smithsonian Institution.

Remarks.—This species differs from *G. hirsuta* and its allies in the bronzy coloring of its upper plumage, and also in being smaller; in the well marked band on the tail feathers it is much like *G. affinis*, but the color of the band is of a deeper black, not bluish black; the tail feathers are narrower than in *affinis*, and the under tail coverts more rufous.

Several specimens examined vary only in some having their upper plumage more of a golden bronze, others being more coppery; none have the under mandible of a clear yellow, some scarcely showing that color, the bill appearing to be entirely black.

2. *EUPHERUSA NIGRIVENTRIS*.

Fore part of the head as far as upon a line with the back part of the eyes, and the entire under surface deep velvety black; occiput dull ashy brown, upper plumage grass green tinged with golden; upper tail coverts of a dull coppery bronze; the four central tail feathers blackish purple, the three lateral on each side pure white; primaries brownish purple; the wing coverts green like the back; the secondaries are chestnut at the base with their ends

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